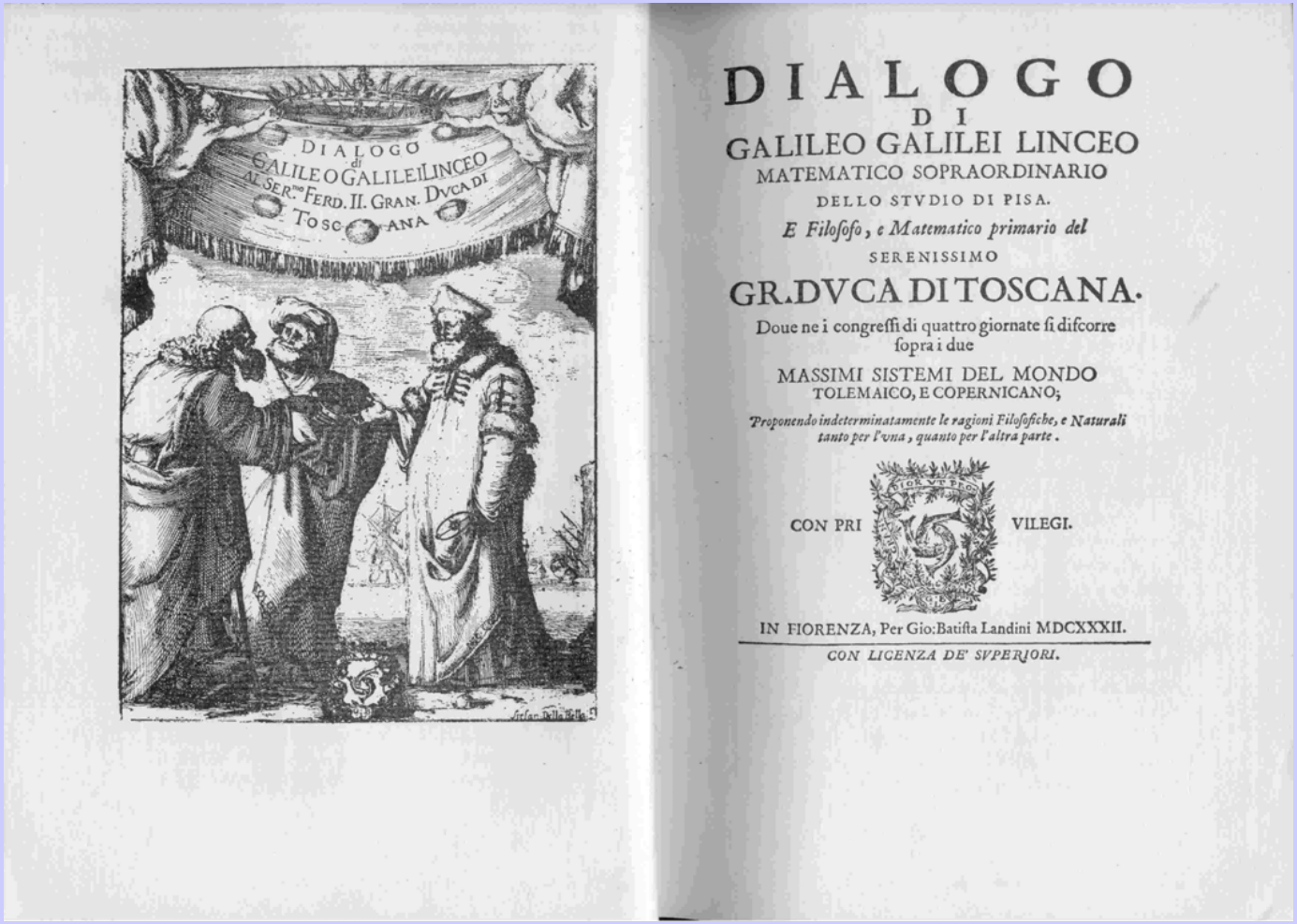
The Living Universe: NASA and the Development of Astrobiology

Steven J. Dick
NASA Chief Historian
GSFC Library Open House
October 20, 2004

Sagitarrius Starscape
David Malin

Two Chief World Systems
17th Century
Geocentric vs. Heliocentric



DIALOGO
DI
GALILEO GALILEI LINCEO
MATEMATICO SOPRAORDINARIO
DELLO STVDIO DI PISA.
E Filosofo, e Matematico primario del
SERENISSIMO
GR. DVCA DI TOSCANA.

Doue ne i congressi di quattro giornate si discorre sopra i due
MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPERNICANO;

Proponendo indeterminatamente le ragioni Filosofiche, e Naturali tanto per l'vna, quanto per l'altra parte.

CON PRI VILEGI.

IN FIORENZA, Per Gio: Batista Landini MDCXXXII.

CON LICENZA DE' SVPERIORI.

Galileo – 1632

Two Chief World Systems
21st Century
The Physical Universe vs. The Biological Universe

Cosmic Evolution

Big Bang
Galaxies
Stars
Biogenic Elements
Planets
Chemical Evolution
Origin of Life

Precambrian Biology
Complex Life
Intelligent Life
Cultural Evolution
Civilizations
Science and Technology
Study of Life in the Universe

Source: NASA SETI Program, 1979

The Biological Universe: Controversial

Giordano Bruno
Piazza Campo dei Fiori
Rome

The Biological Universe: Long-Term Problem

Mid-17th century Jesuit view.
The Copernican system is still
Outweighed by the hybrid
Tychonic system. The geocentric
System is discarded at bottom.

Riccioli, *Almagestum Novum*,1651

Astrobiology and the Biological Universe

- The Triumph of Cosmic Evolution
- Coalescence into a New Discipline
- Astrobiology Today
- Implications of a Biological Universe

M 31/ Gendler

The Triumph of Cosmic Evolution

A Universe 3600 Light Years in Extent

A. R. Wallace, 1903

MAN'S PLACE IN THE UNIVERSE

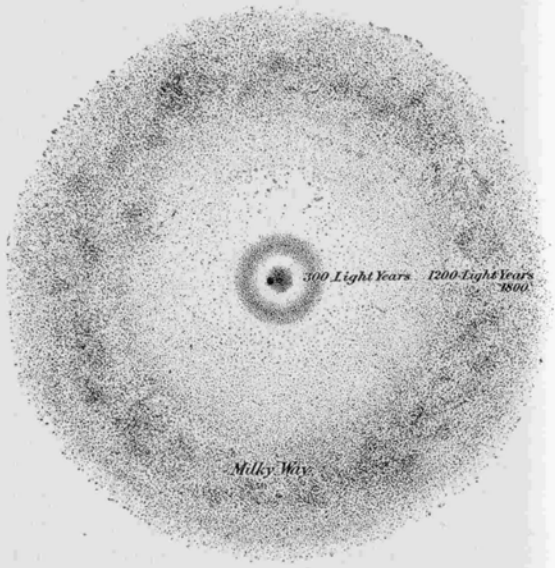
A STUDY OF THE RESULTS OF SCIENTIFIC RESEARCH IN RELATION TO THE UNITY OR PLURALITY OF WORLDS

BY

ALFRED R. WALLACE, LL.D., D.C.L., F.R.S.

NEW YORK
McCLURE, PHILLIPS & CO.
MCMIII

DIAGRAM OF STELLAR UNIVERSE (Plan)



1. Central part of Solar Cluster.
2. Sun's Orbit (black spot).
3. Outer limit of Solar Cluster.
4. Milky Way.

are on the same scale, and they show the total diameter across the Milky Way as being 3600 light-years, or about half that

A Universe Billions of Light Years in Extent

Late 20th Century

Hubble Deep Field, R. Williams, the HDF Team (STScI), NASA

Shapley on Cosmic Evolution

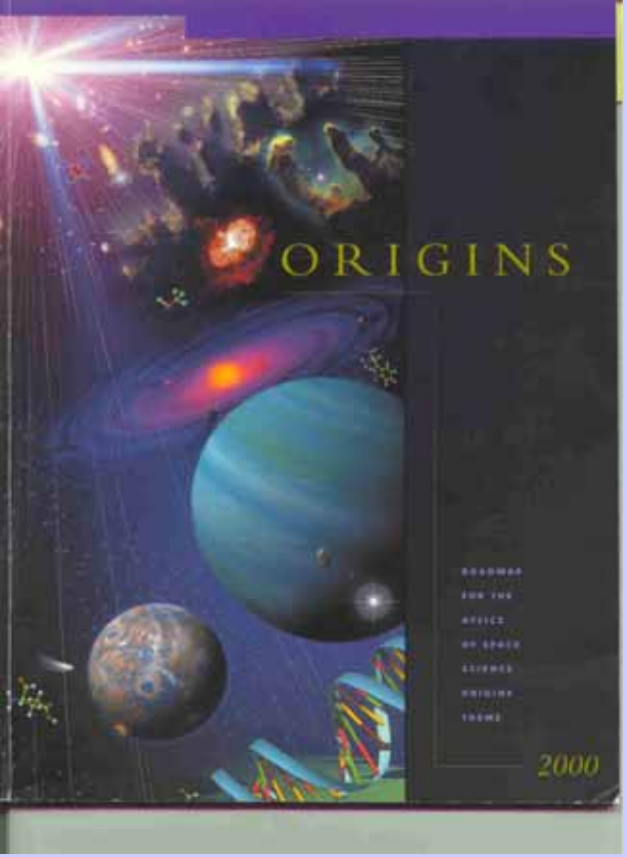
The Earth and its life are “on the outer fringe of one galaxy in a universe of millions of galaxies. Man becomes peripheral among the billions of stars in his own Milky Way; and according to the revelations of paleontology and geochemistry he is also exposed as a recent, and perhaps an ephemeral manifestation in the unrolling of cosmic time.”

Harlow Shapley
Of Stars and Men, 1958

Cosmic Evolution

David DesMarais, Thomas Scattergood and Linda Jahnke/ NASA Ames, 1986, reissued 1997.

Cosmic Evolution according to NASA (1997)

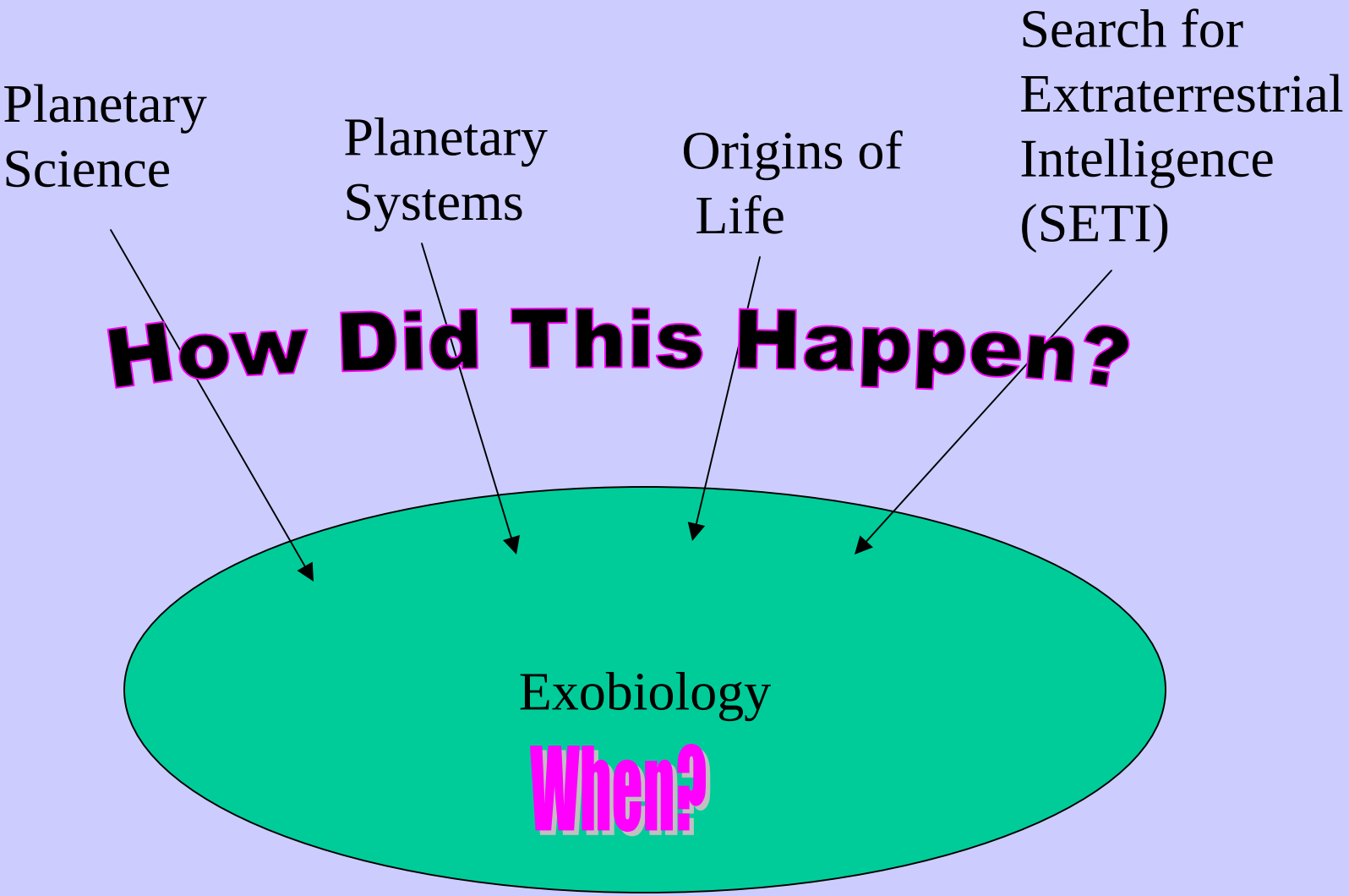


NASA and Cosmic Evolution

Following the 15 billion year long chain of events from the birth of the universe at the Big Bang, through the formation of chemical elements, galaxies, stars, and planets, through the mixing of chemicals and energy that cradles life on Earth, to the earliest self-replicating organisms – and the profusion of life

Coalescence of a New Discipline: Foundations of Exobiology To 1965

Coalescence of a New Discipline



Planetary Science:
The Copernican Foundation

John Wilkins, *Discourse Concerning a new World And Another Planet* (1640)

The Moon and the planets
Are potential Earth-like worlds

Evidence of Life on Mars, 1894

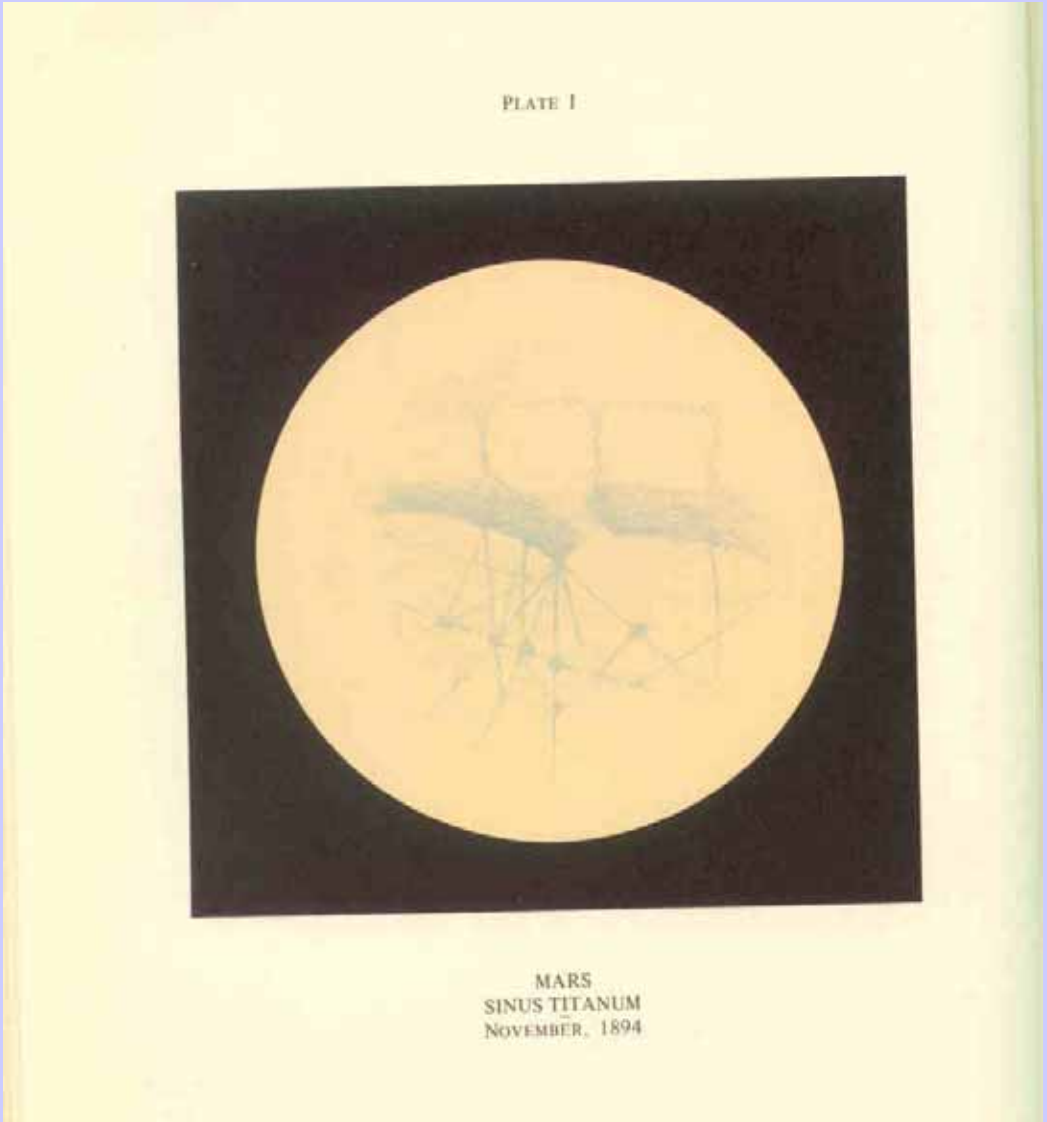


PLATE I

MARS
SINUS TITANUM
NOVEMBER, 1894

Lowell, *Mars* (1894)

Martian Vegetation?

Seasonal surface variations
E. C. Slipher, 1924-1926

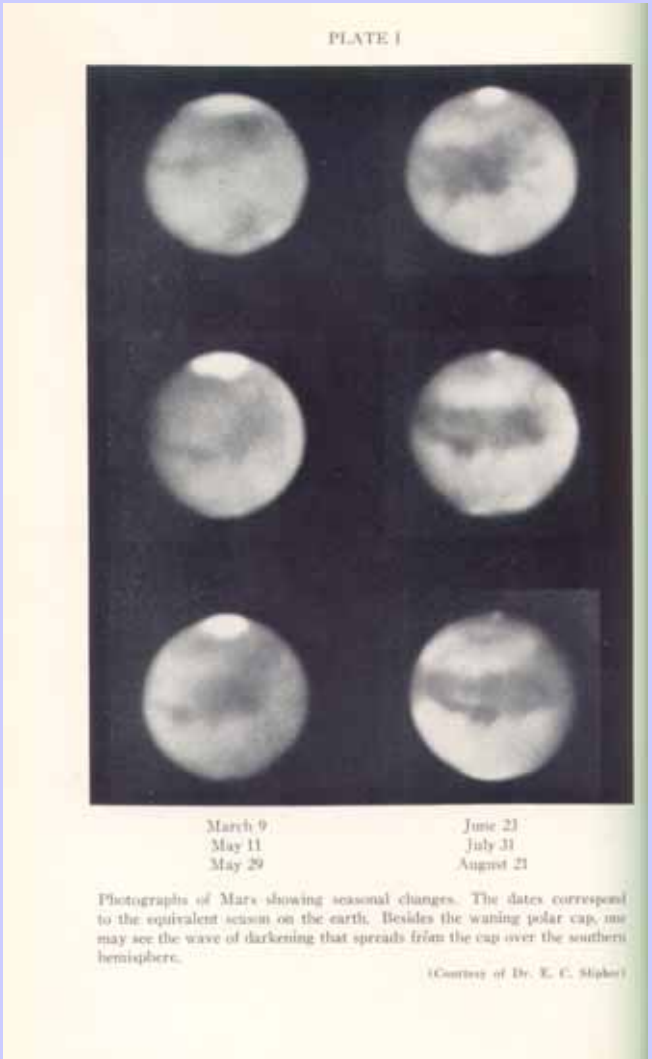


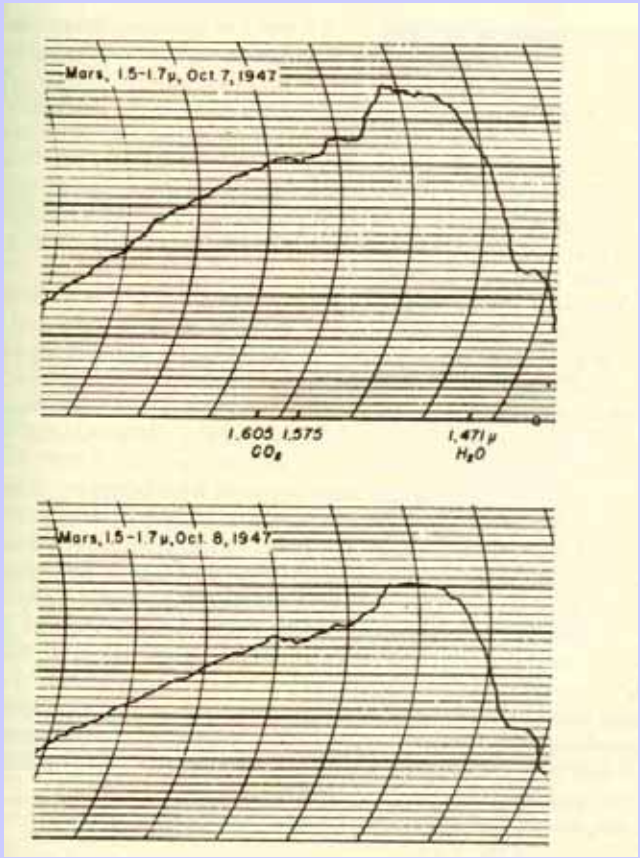
PLATE I

March 9 — June 23
May 11 — July 31
May 29 — August 23

Photographs of Mars showing seasonal changes. The dates correspond to the equivalent season on the earth. Besides the waning polar cap, one may see the wave of darkening that spreads from the cap over the southern hemisphere.

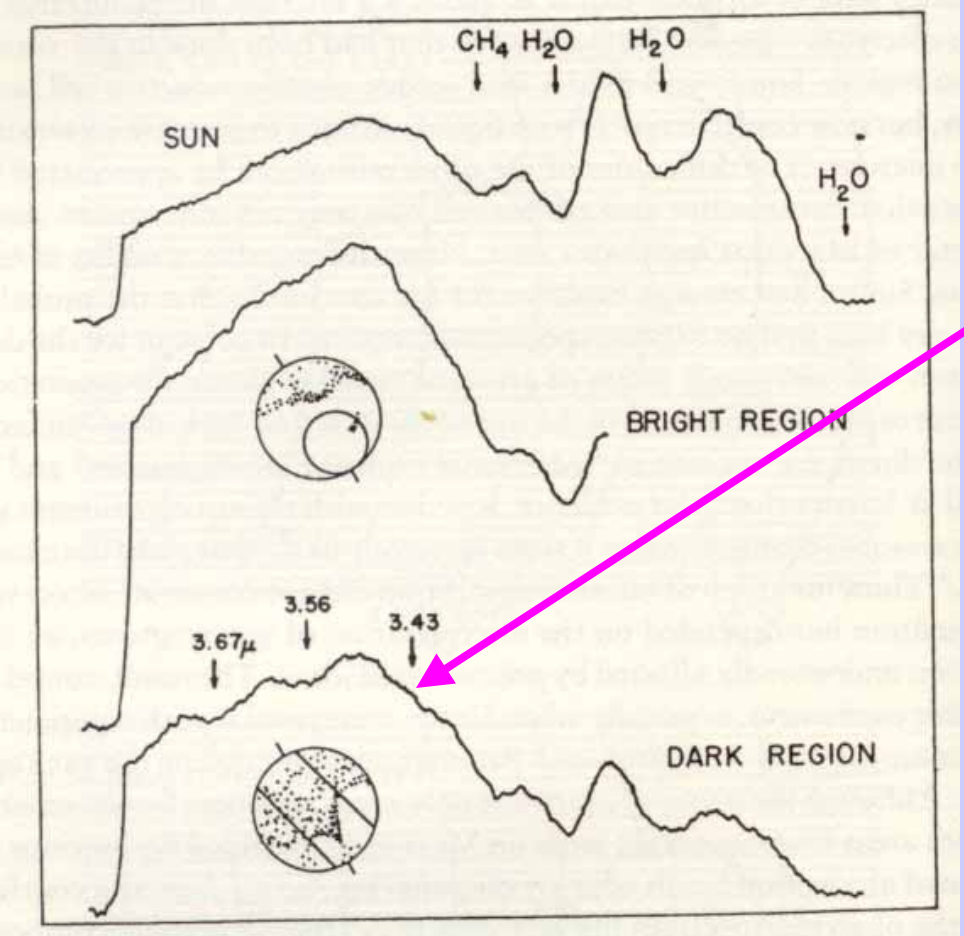
(Courtesy of Dr. E. C. Slipher)

Kuiper – CO2 on Mars, 1947
Plant life?



Carbon dioxide bands on
Mars in 1.6 micron region
Using infrared spectrometer on
McDonald 82-inch, 1947

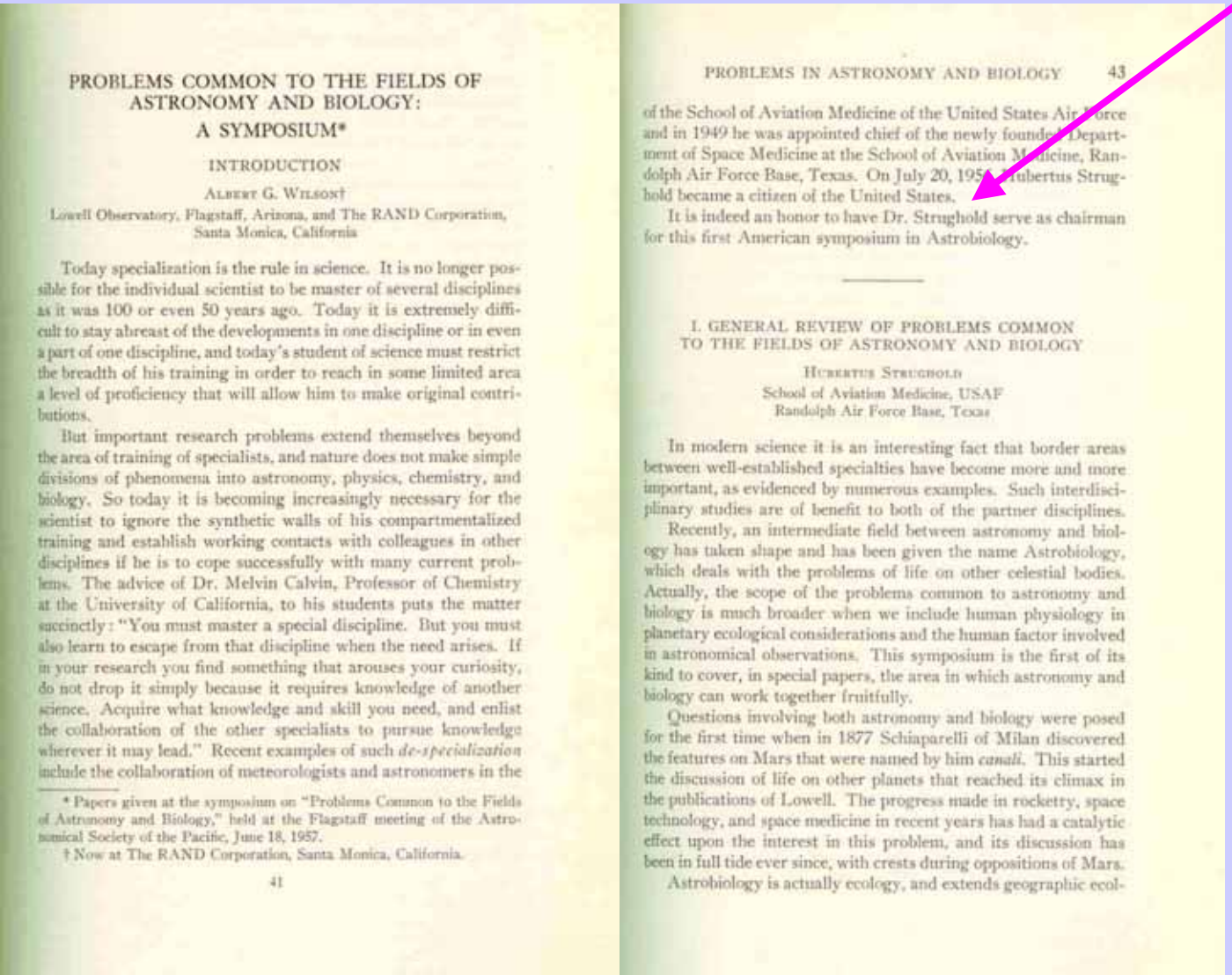
Evidence of Life on Mars, 1959



Near-infrared absorptions On dark areas of Mars Interpreted as due to vegetation

William Sinton, "Further Evidence of Vegetation on Mars," Science (Nov. 6, 1959).

First American Symposium on Astrobiology – 1957!



PROBLEMS COMMON TO THE FIELDS OF ASTRONOMY AND BIOLOGY: A SYMPOSIUM*

INTRODUCTION

ALBERT G. WILSON†
Lowell Observatory, Flagstaff, Arizona, and The RAND Corporation, Santa Monica, California

Today specialization is the rule in science. It is no longer possible for the individual scientist to be master of several disciplines as it was 100 or even 50 years ago. Today it is extremely difficult to stay abreast of the developments in one discipline or in even a part of one discipline, and today's student of science must restrict the breadth of his training in order to reach in some limited area a level of proficiency that will allow him to make original contributions.

But important research problems extend themselves beyond the area of training of specialists, and nature does not make simple divisions of phenomena into astronomy, physics, chemistry, and biology. So today it is becoming increasingly necessary for the scientist to ignore the synthetic walls of his compartmentalized training and establish working contacts with colleagues in other disciplines if he is to cope successfully with many current problems. The advice of Dr. Melvin Calvin, Professor of Chemistry at the University of California, to his students puts the matter succinctly: "You must master a special discipline. But you must also learn to escape from that discipline when the need arises. If in your research you find something that arouses your curiosity, do not drop it simply because it requires knowledge of another science. Acquire what knowledge and skill you need, and enlist the collaboration of the other specialists to pursue knowledge wherever it may lead." Recent examples of such *de-specialization* include the collaboration of meteorologists and astronomers in the

* Papers given at the symposium on "Problems Common to the Fields of Astronomy and Biology," held at the Flagstaff meeting of the Astronomical Society of the Pacific, June 18, 1957.

† Now at The RAND Corporation, Santa Monica, California.

of the School of Aviation Medicine of the United States Air Force and in 1949 he was appointed chief of the newly founded Department of Space Medicine at the School of Aviation Medicine, Randolph Air Force Base, Texas. On July 20, 195[illegible] Hubertus Strughold became a citizen of the United States.

It is indeed an honor to have Dr. Strughold serve as chairman for this first American symposium in Astrobiology.

I. GENERAL REVIEW OF PROBLEMS COMMON TO THE FIELDS OF ASTRONOMY AND BIOLOGY

HUBERTUS STRUGHOLD
School of Aviation Medicine, USAF
Randolph Air Force Base, Texas

In modern science it is an interesting fact that border areas between well-established specialties have become more and more important, as evidenced by numerous examples. Such interdisciplinary studies are of benefit to both of the partner disciplines.

Recently, an intermediate field between astronomy and biology has taken shape and has been given the name Astrobiology, which deals with the problems of life on other celestial bodies. Actually, the scope of the problems common to astronomy and biology is much broader when we include human physiology in planetary ecological considerations and the human factor involved in astronomical observations. This symposium is the first of its kind to cover, in special papers, the area in which astronomy and biology can work together fruitfully.

Questions involving both astronomy and biology were posed for the first time when in 1877 Schiaparelli of Milan discovered the features on Mars that were named by him *canali*. This started the discussion of life on other planets that reached its climax in the publications of Lowell. The progress made in rocketry, space technology, and space medicine in recent years has had a catalytic effect upon the interest in this problem, and its discussion has been in full tide ever since, with crests during oppositions of Mars.

Astrobiology is actually ecology, and extends geographic ecol-

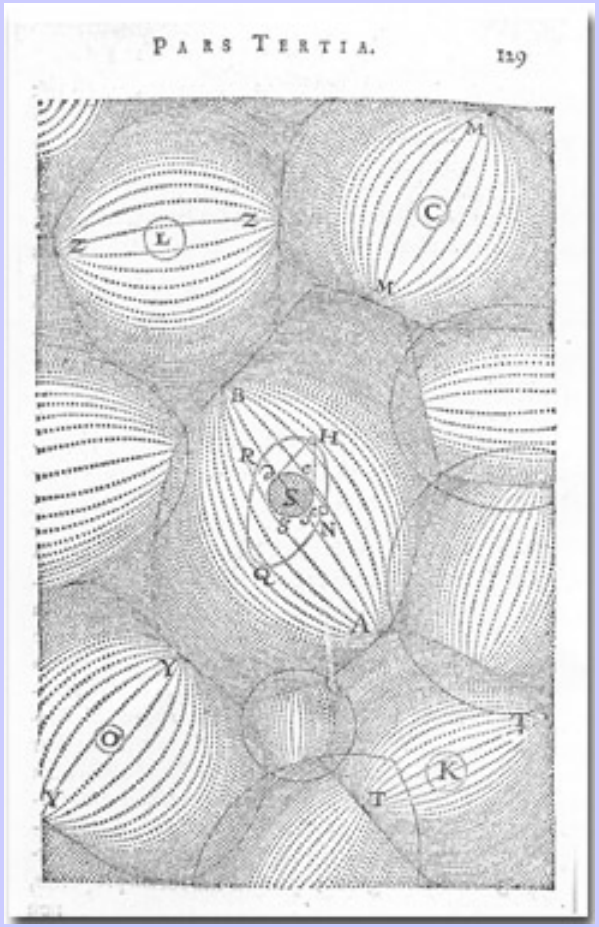
Strughold
Dollfus
Sinton
Etc.

PASP, 70 (1958), 41-78

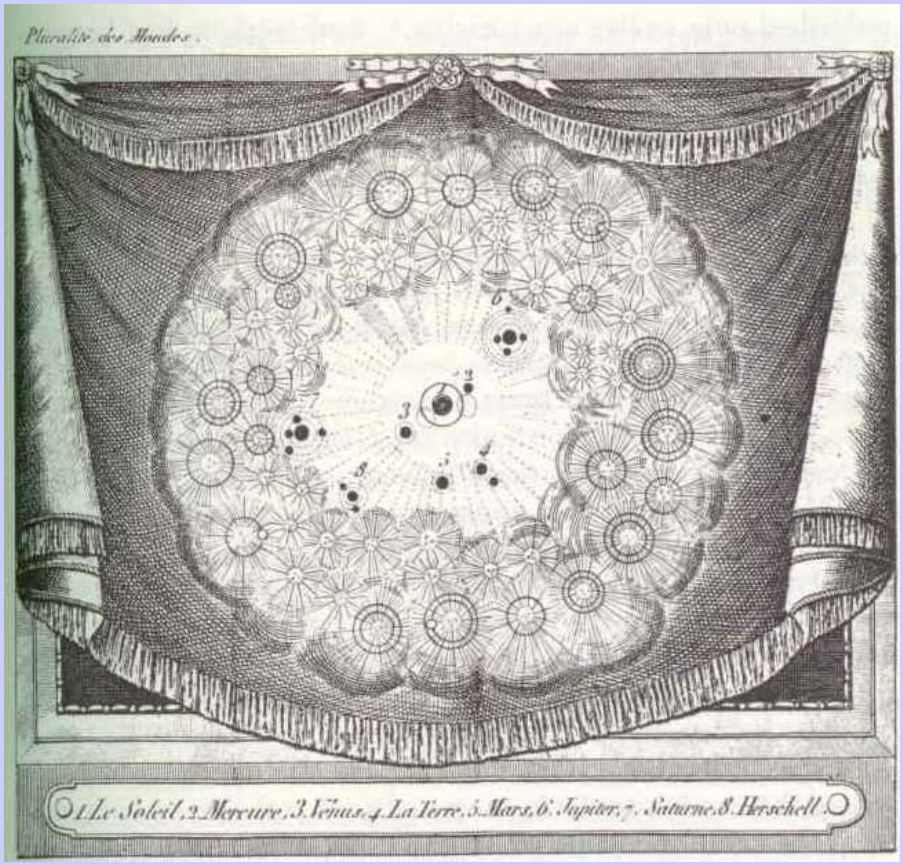
Exploration by Spacecraft

- Lederberg and planetary contamination issue leads to “Exobiology”
- NASA sets up life science lab at Ames
- Space Science Board/NAS sets search for extraterrestrial life as “prime goal of space biology.”
- Exploration of Mars by spacecraft begins

Planetary Systems – The 17th Century Foundation

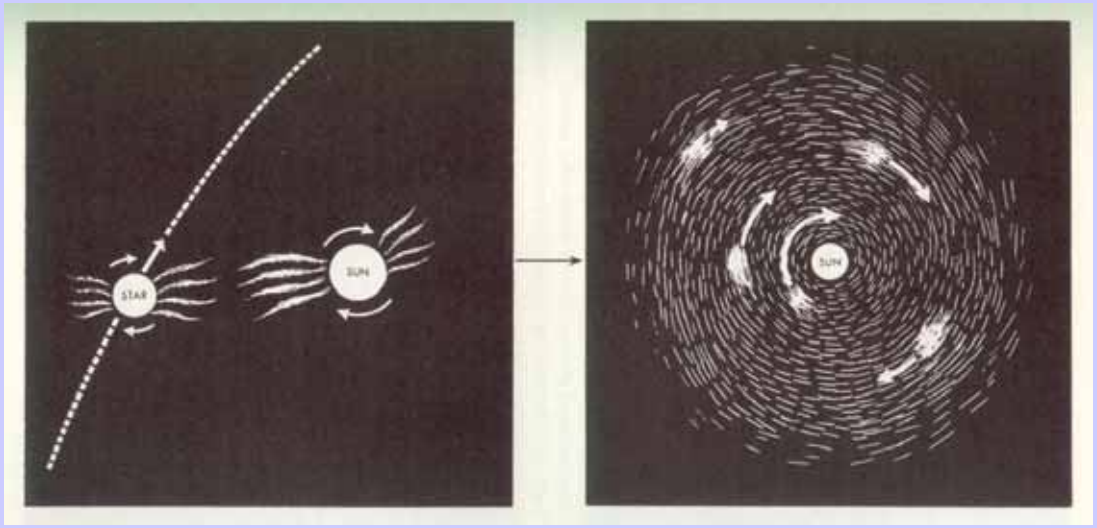


Descartes, 1644

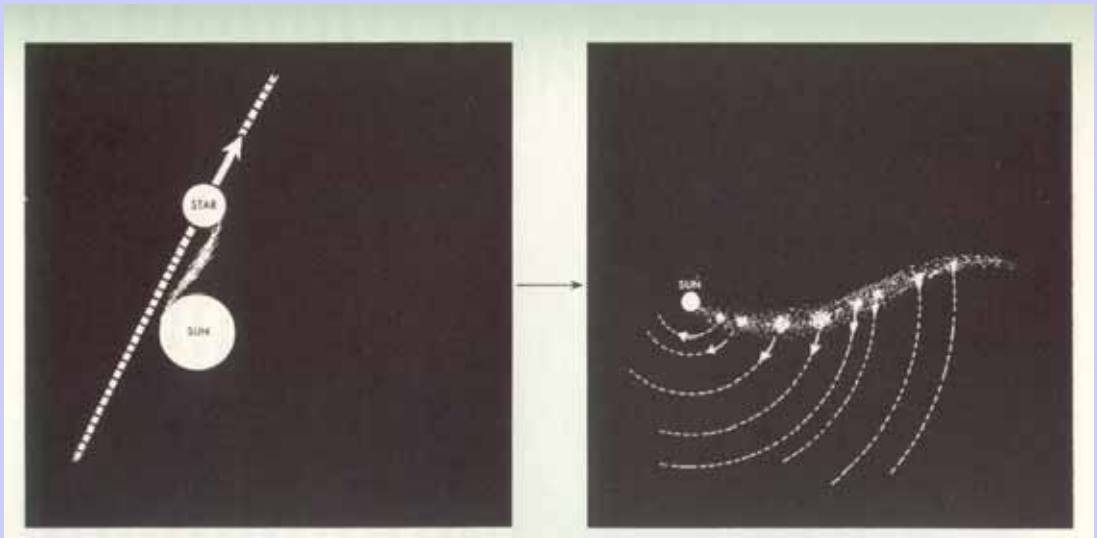


Fontenelle, 1686 (1821 ed.)

Tidal Hypothesis vs Nebular Hypothesis



Chamberlin-Moulton
(1905)



Jeans-Jeffreys
(1917)

From Thornton Page,
Physics Today (October, 1948)

Planetary Systems – Turning Point

Table 2.2 Estimates of Frequency of Planetary Systems, 1920-1961

Author	Argument	No. of planetary Sytems in galaxy	No. of habitable planets in galaxy
Jeans (1919, 1923)	Tidal theory	Unique	1
Shapley (1923)	Tidal theory	"Unlikely"	"Uncommon"
Russell (1926)	Tidal theory "Speculation"	"Infrequent"	
Jeans (1941)	No. of stars	10^2	-
Jeans (1942)	Improved tidal Abundant	One in six stars	
Russell (1943)	Companions	Very large	$> 10^3$
Page (1948)	Weizsäcker	$> 10^9$	$> 10^6$
Struve (1950)	Stellar rotation		
Kuiper (1951)	Binary star statistics	10^9	-
Hoyle (1955)	Stellar rotation	10^{11}	-
Shapley (1958)	Nebular hypothesis	10^6-10^9	-
Huang (1950)	Stellar rotation	10^9	10^9
Hoyle (1960)	Stellar rotation	10^{11}	10^9
Struve (1961)	Stellar rotation	$>10^9$	-

Adapted from Dick (1996), p. 199

Radial Velocity Planet Search – 1952!

there is a good chance that by using somewhat larger equipment at the next eclipse, definite and accurate measurements of line width will become available.

I should like to say here how indebted we are to Professor Redman who at very short notice acquired a site for us at Khartoum and without whose assistance we should hardly have been able to set up our instruments in the short time available to us.

Mr. Sadler. I ask you to return your thanks to Prof. Brück and to all those who have taken part in this Colloquium. It is my task to predict eclipses, not to observe them but we have all found these preliminary accounts of the results expected, with varying degrees of optimism, most interesting. The meeting is now adjourned at $12^h\ 40^m$.

PROPOSAL FOR A PROJECT OF HIGH-PRECISION STELLAR RADIAL VELOCITY WORK

By Otto Struve

With the completion of the great radial-velocity programmes of the major observatories, the impression seems to have gained ground that the measurement of Doppler displacements in stellar spectra is less important at the present time than it was prior to the completion of R. E. Wilson's new radial-velocity catalogue.

I believe that this impression is incorrect, and I should like to support my contention by presenting a proposal for the solution of a characteristic astrophysical problem.

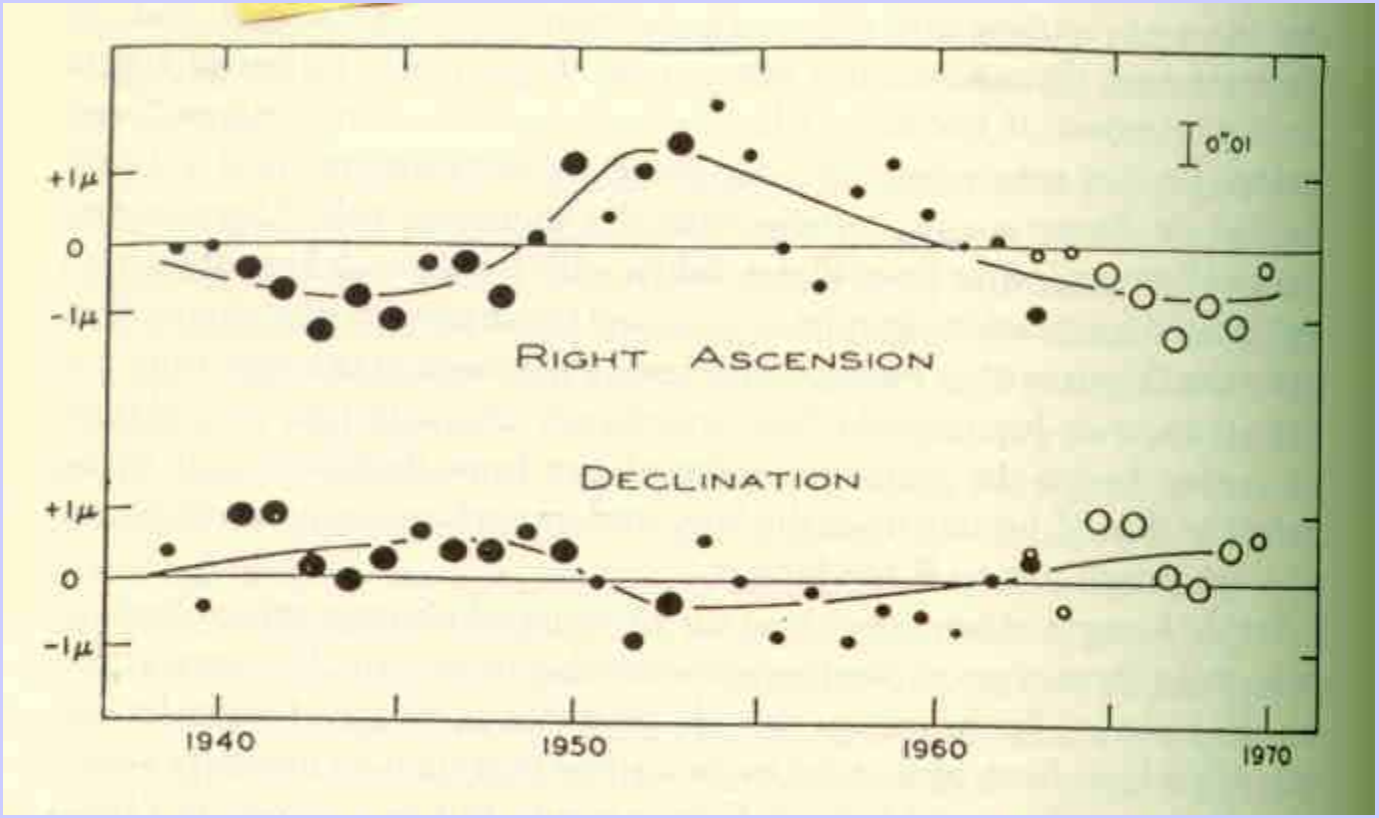
One of the burning questions of astronomy deals with the frequency of planet-like bodies in the galaxy which belong to stars other than the Sun. K. A. Strand's[1] discovery of a planet-like companion in the system of 61 Cygni, which was recently confirmed by A. N. Deitch[2] at Poulkovo, and similar results announced for other stars by P. Van de Kamp[3] and D. Reuyl and E. Holmberg[4] have stimulated interest in this problem. I have suggested elsewhere that the absence of rapid axial rotation in all normal solar-type stars (the only rapidly-rotating G and K stars are either W Ursae Majoris binaries or T Tauri nebular variables,[5] or they possess peculiar spectra[6]) suggests that these stars have somehow converted their angular momentum of axial rotation into angular momentum of orbital motions of planets. Hence, there may be many objects of planet-like character in the galaxy.

But how should we proceed to detect them? The method of direct photography used by Strand is, of course, excellent for nearby binary

- Suggests planetary companions might exist with 1 day period!
- Resulting in radial velocity oscillations of 200 m/sec for Jupiter mass planet.
- Detectable with Coude spectrograph
- Eclipses resulting in .02 mag dip!

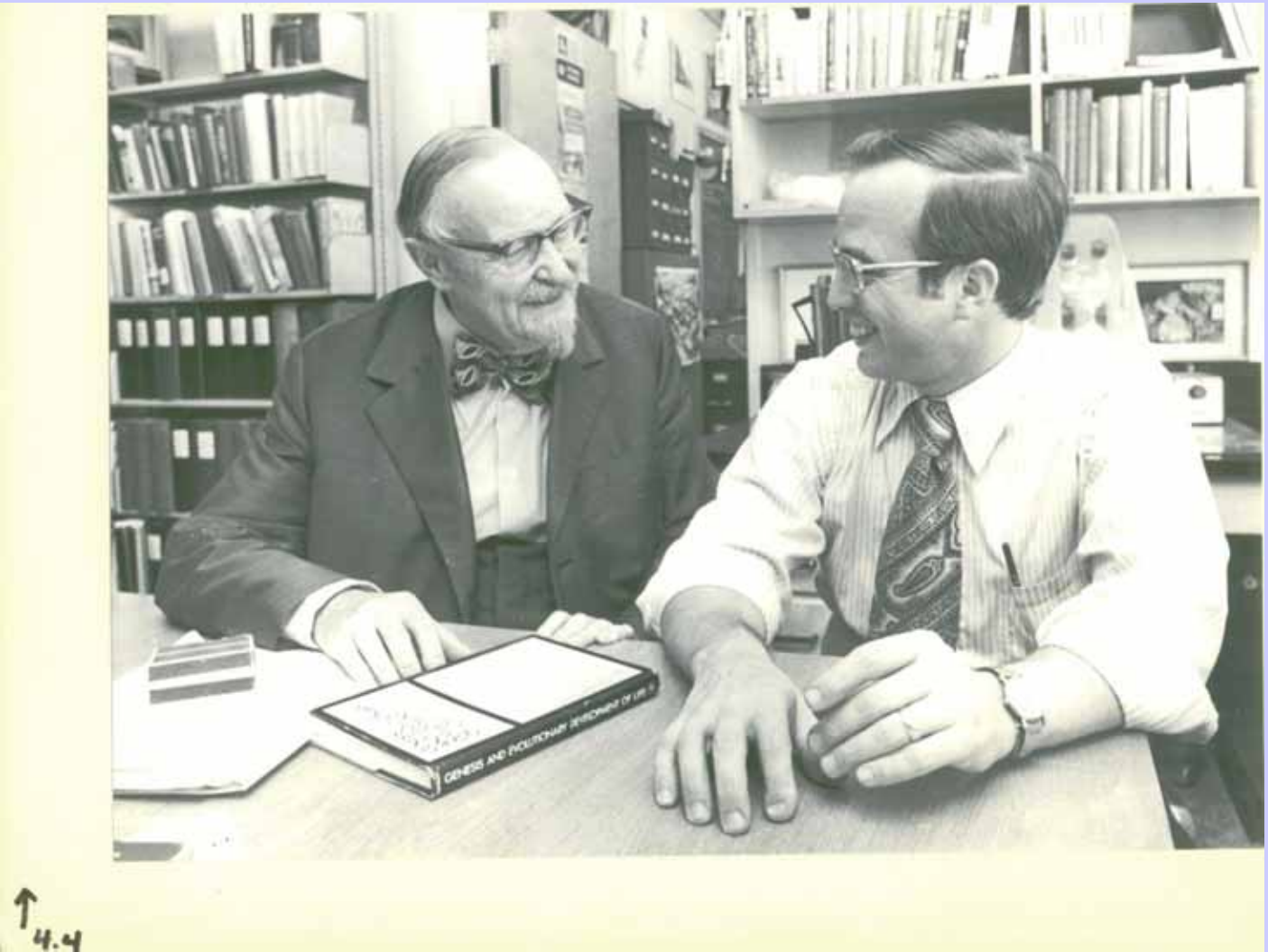
Observatory, 72 (1952), 199

Van de Kamp's Claim



Barnard's Star
AJ, 1963

Origins of Life

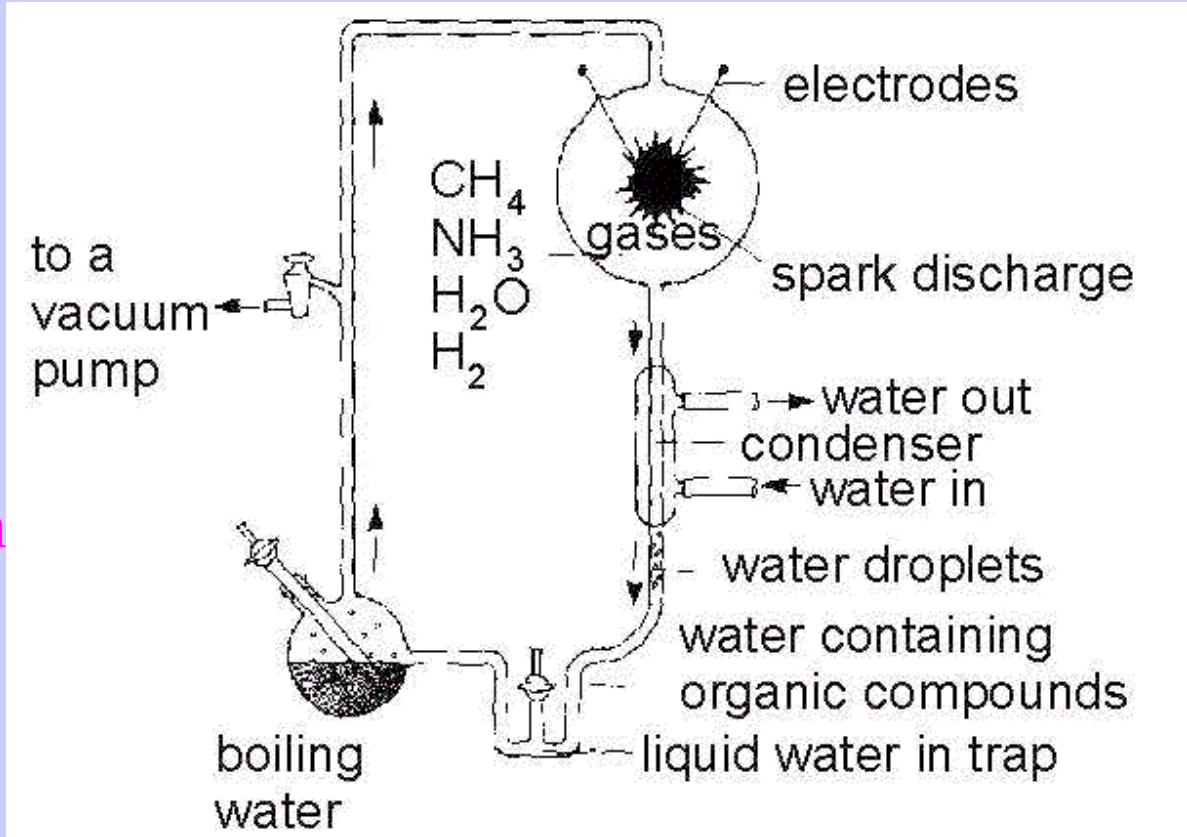


Alex. I. Oparin
Bill Schopf

↑ 4.4

Origins of Life

Miller-Urey Experiment, 1953

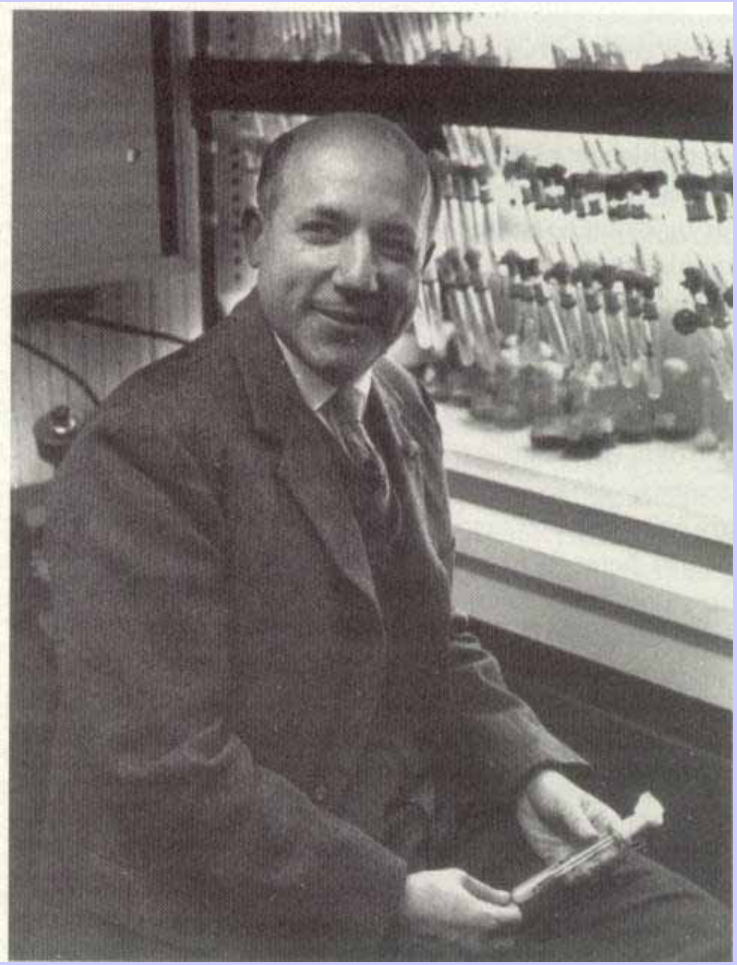


Synthesis of amino acids in A presumed primitive Earth atmosphere (methane and ammonia)

Origins of Life and Astrobiology: The Inseparable Connection

Surely one of the most marvelous feats of the 20th century Would be the firm proof that life exists on another planet. All the projected space flights and the high costs of such developments would be fully justified if they were able to establish the existence of life on either Mars or Venus. In that case, the thesis that life develops spontaneously when the conditions are favorable would be far more firmly established, and our whole view of the problem of the origin of life would be confirmed.

Miller and Urey, 1959



Melvin Calvin, Prof. Of Chemistry
University of California

Nobelist for work on photosynthesis

"You must master a special discipline.
But you must also learn to escape from
That discipline when the need arises.
If in your research you find something
That arouses your curiosity, do not drop
It simply because it requires knowledge
Of another science. Acquire what
Knowledge and skill you need, and
Enlist the collaboration of the other
Specialists to pursue knowledge
Wherever it may lead"

SETI – Search for Extraterrestrial Intelligence

RADIO TO STARS, MARCONI'S HOPE

Inventor Says Waves of Ether Are Eternal and Can Reach Other Planets.

GETS STRANGE SIGNALS NOW

These, He Declares, Might Conceivably Have Proceeded from Other Worlds.

Special Cable to THE NEW YORK TIMES.

LONDON, Jan. 20.—The Daily Chronicle publishes an interview which Harold Begbie had with William Marconi, in the course of which the latter discussed the possibility of communicating by wireless with the stars.

Mr. Begbie asked him if he thought that waves of ether were eternal. Mr. Marconi replied:

"Yes, I do. Messages that I sent off ten years ago have not yet reached some of the nearest stars. When they arrive there why should they stop? It is like an attempt to express one-third as a decimal fraction; you can go on forever without coming to any sign of an end. That is what makes me hope for a very big thing in the future."

"What is that?" asked Mr. Begbie.

Marconi, New York Times, 1920

SHORT WAVE & TELEVISION for DECEMBER, 1937

Can We Signal MARS by Short Wave?

The Possibility of Interplanetary Communication

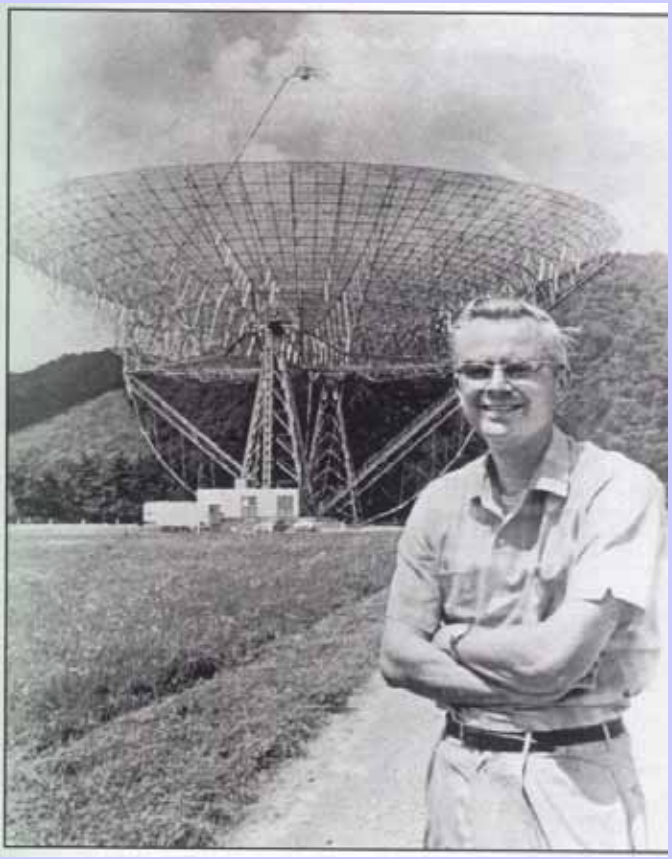
Including the Views of Dr. Lee de Forest and Nikola Tesla

By Dr. Donald H. Menzel

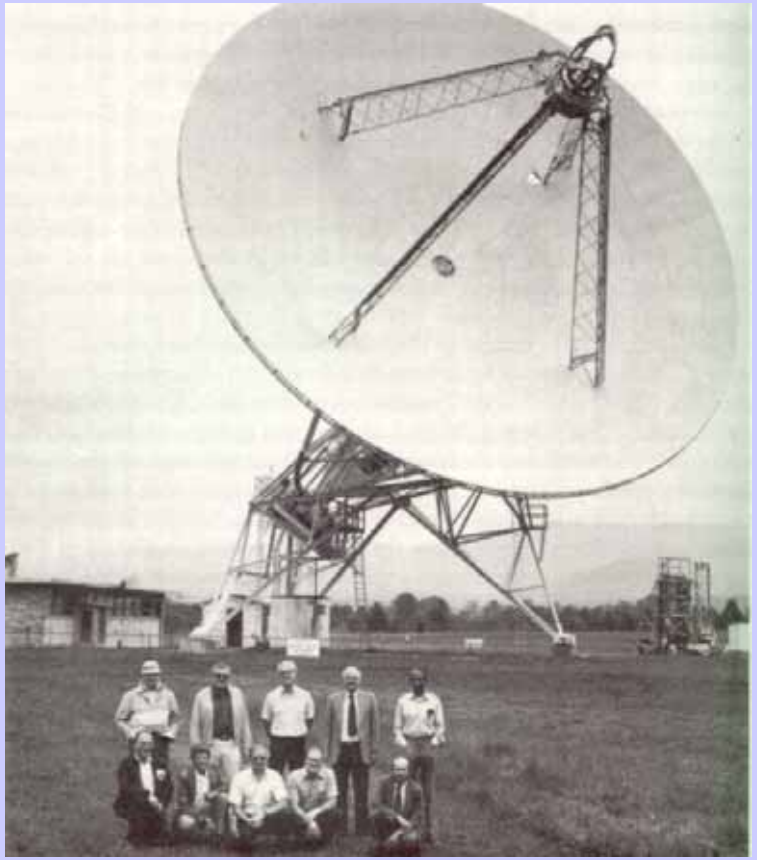
Associate Professor of Astronomy, Harvard University.

Menzel, Shortwave & Television, 1937

SETI – Project Ozma



300-foot
(later destroyed by aliens)

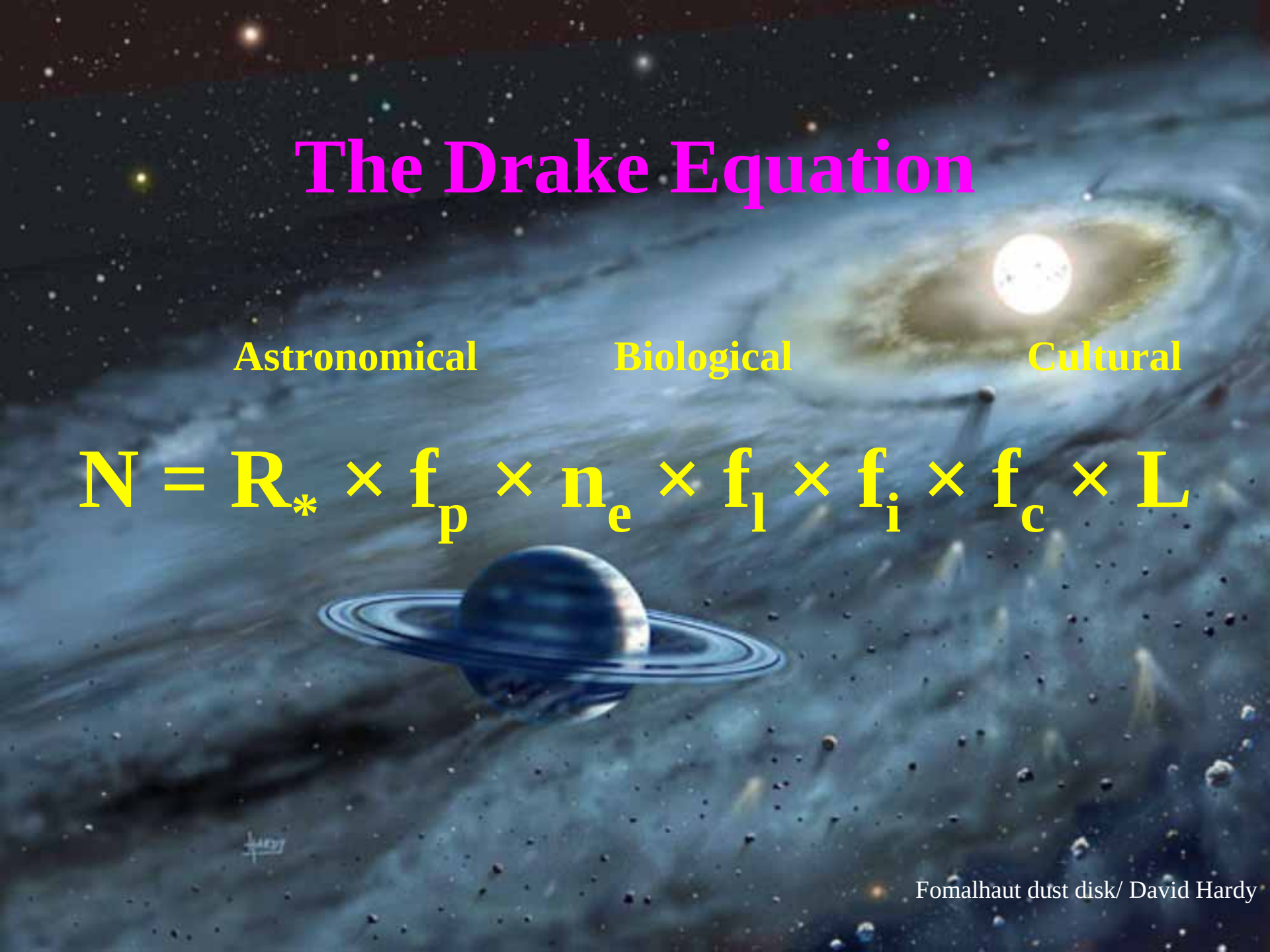


Project Ozma Team reassembled for the 25th anniversary, 1975 in front of the 85-foot Tatel telescope.

The Drake Equation

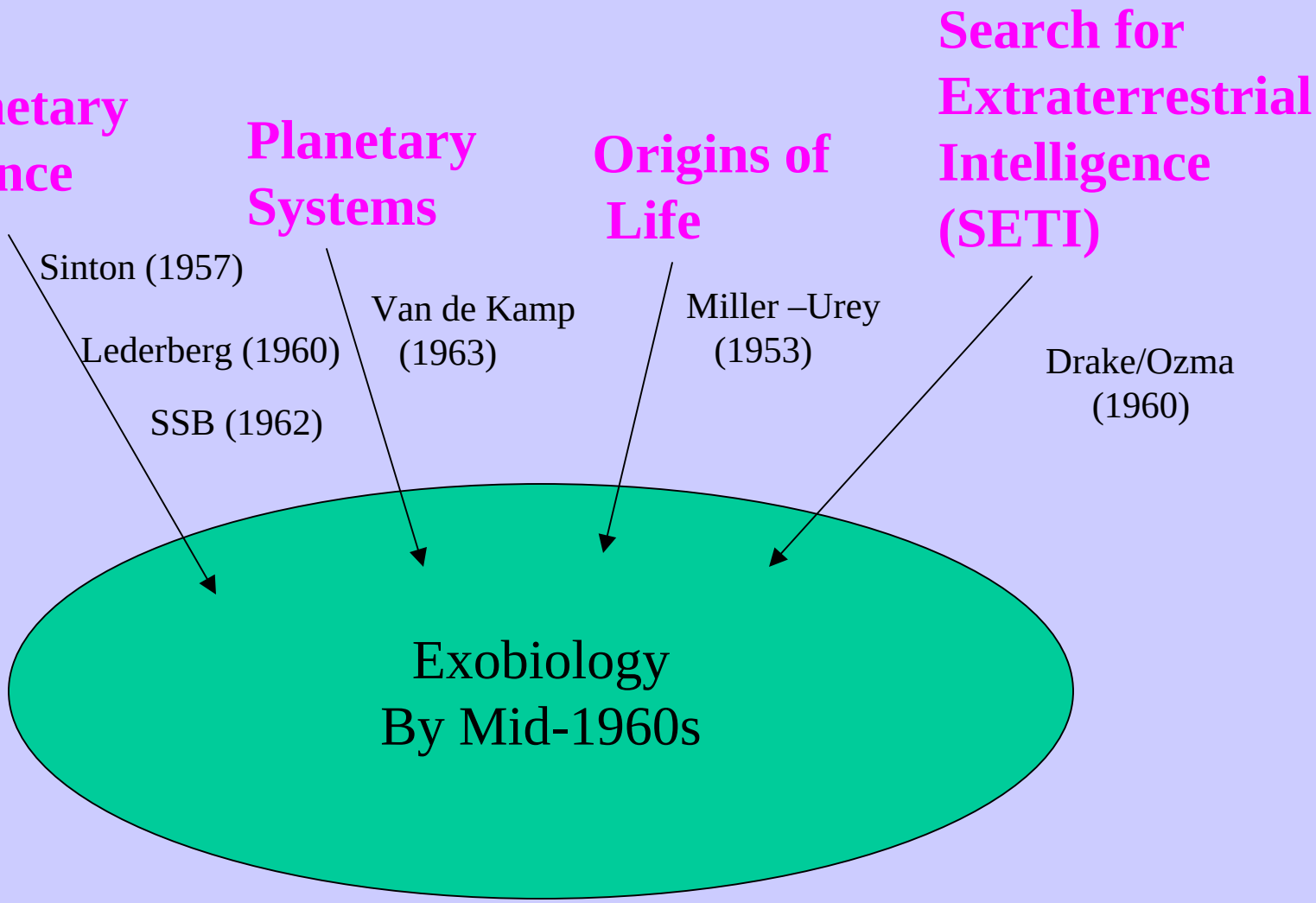
Astronomical Biological Cultural

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$



Fomalhaut dust disk/ David Hardy

Coalescence of a New Discipline



Declarations of a Discipline

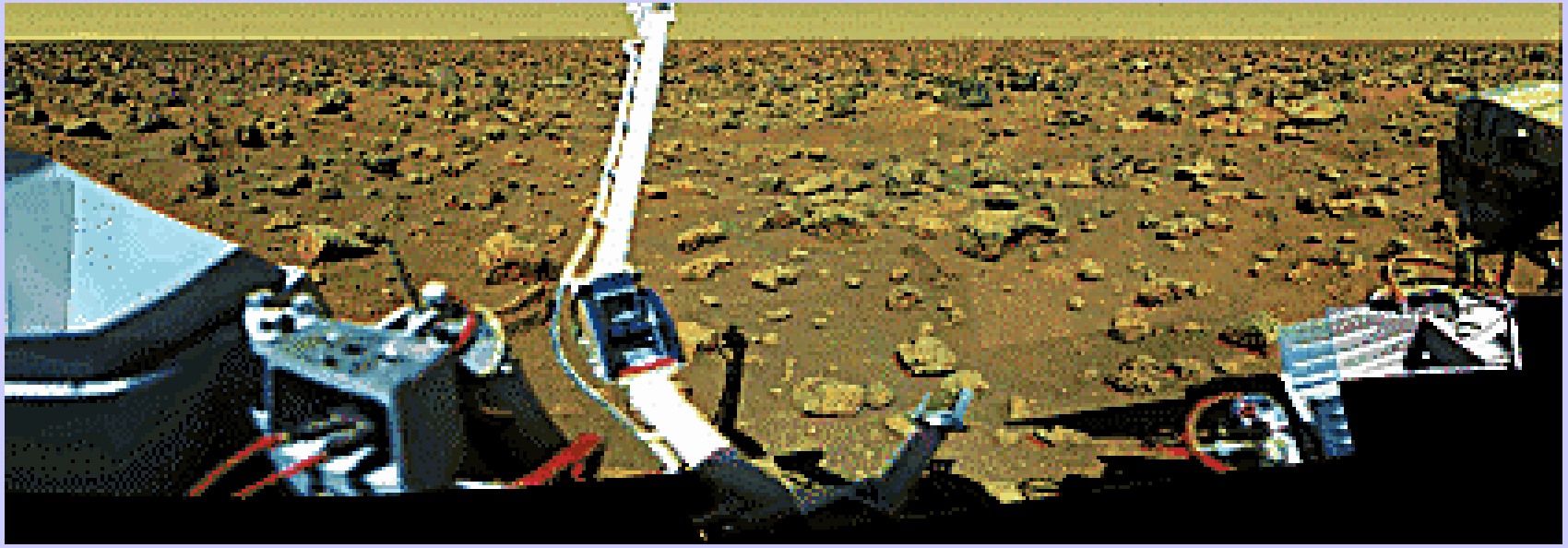
- **Otto Struve on "astrobiology" (1955): "The time is probably not yet ripe to recognize such a completely new discipline within the framework of astronomy"**

- **Joshua Lederberg (1960): Sets the agenda and coins the term "exobiology", "Exobiology: Experimental Approaches to Life Beyond Earth," Science, 132 (1960).**

- **I. S. Shklovskii (1965): "we are witnessing the inception of a new science, which occupies a boundary position between astrophysics, biology, engineering and even sociology"**

Astrobiology
A Discipline Revitalized

Viking Results

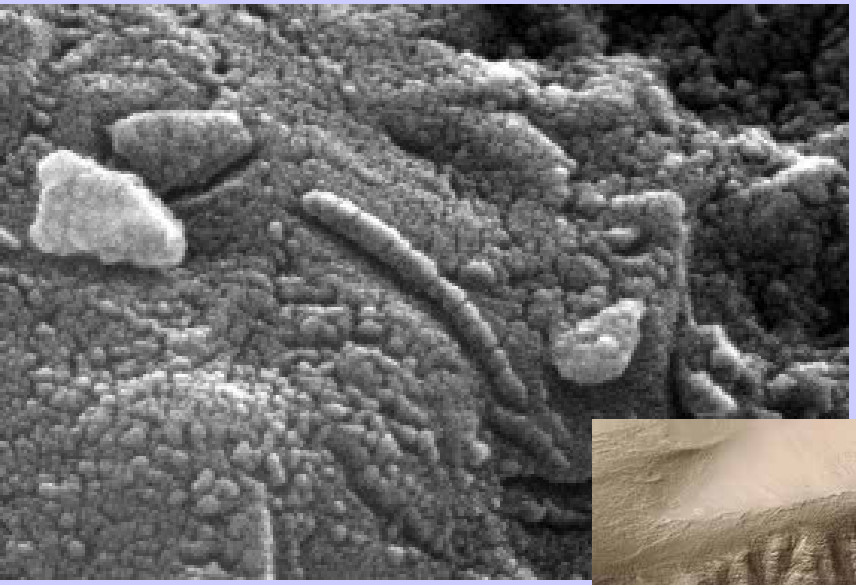


NASA and the Post-Viking Revolutions

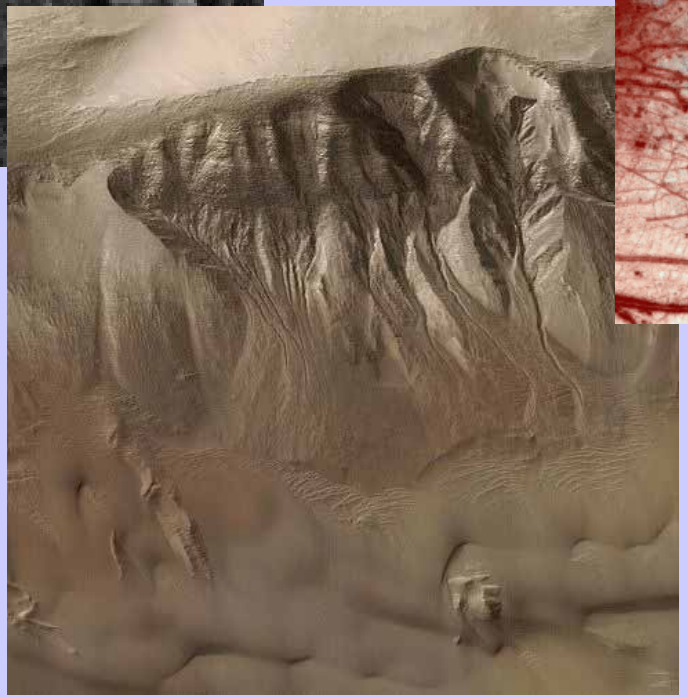
Exobiology Program Funded:

- Three Domains of life Research (Woese)
- Precambrian microfossils (Barghoorn and Schof)
- Gaia hypothesis (Lovelock and Margulis)
- Mass extinction work (Alvarez, Raup and Sepkoski)
- Exogenous Delivery (Sagan and Chyba)
- Pre-RNA world (Miller/NSCORT group)

Planetary Science

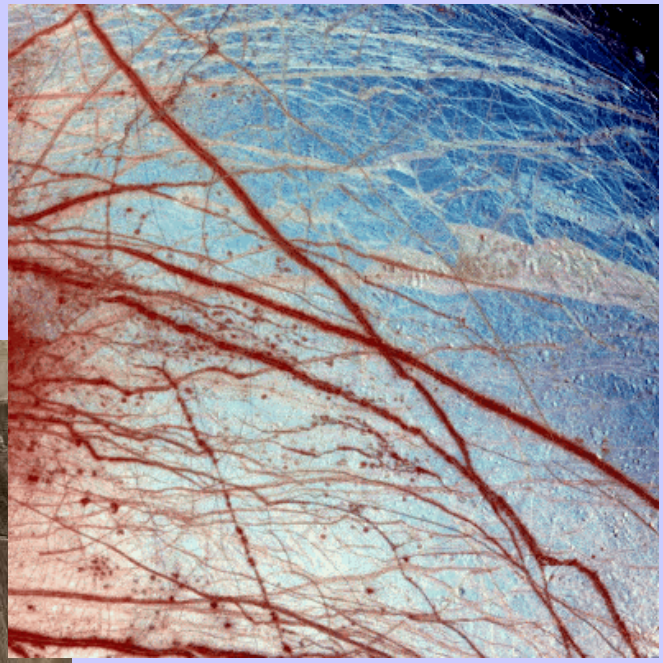


D. McKay,
K. Thomas-Keprta, R. Zare
Mars Rock fossils?



Gullies of Mars
From
Mars Global Surveyor

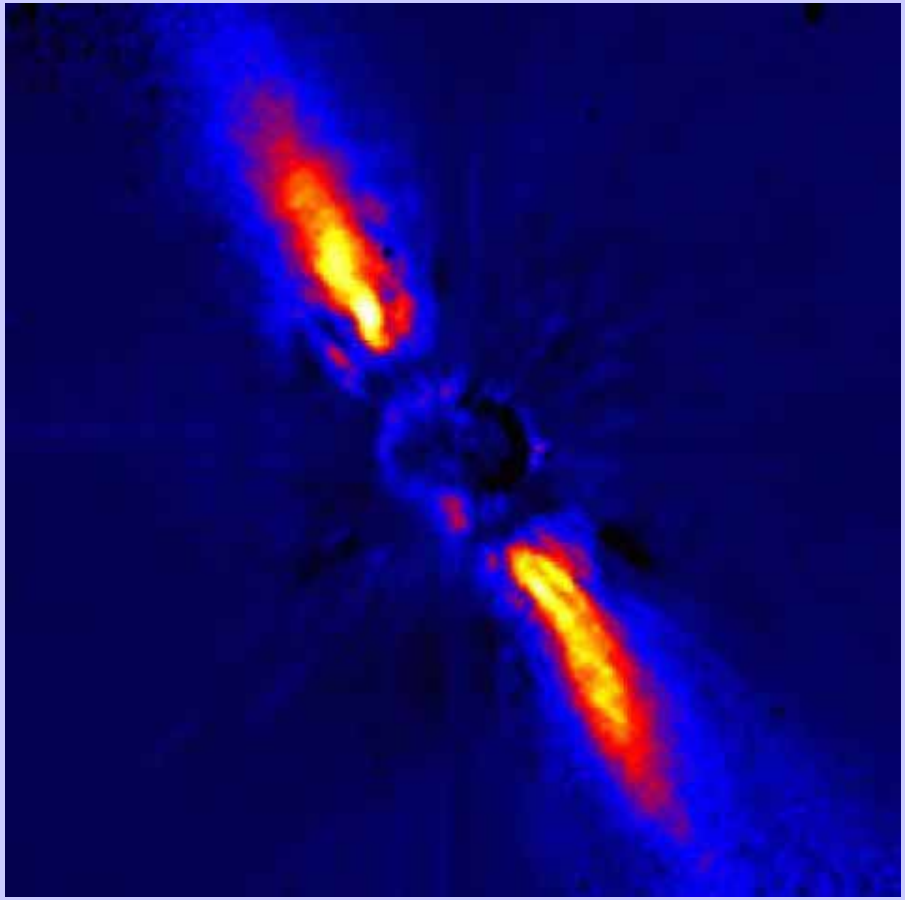
Malin Space Science Systems, MGS,
JPL, NASA



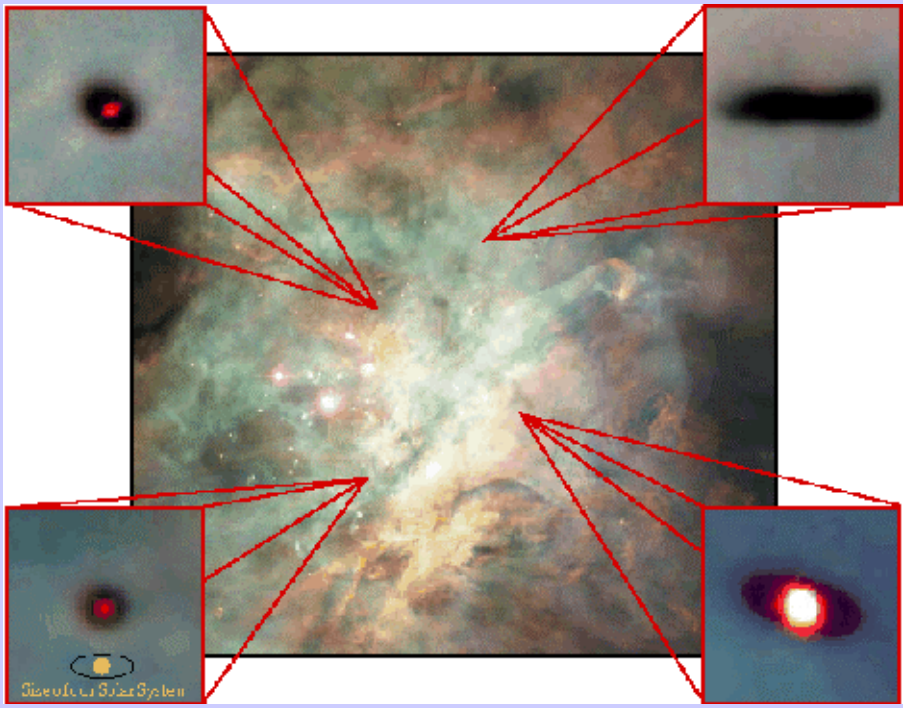
Cracked Ice Plains of Europa
Galileo Project, JPL, NASA

Circumstellar disks

Beta Pictoris

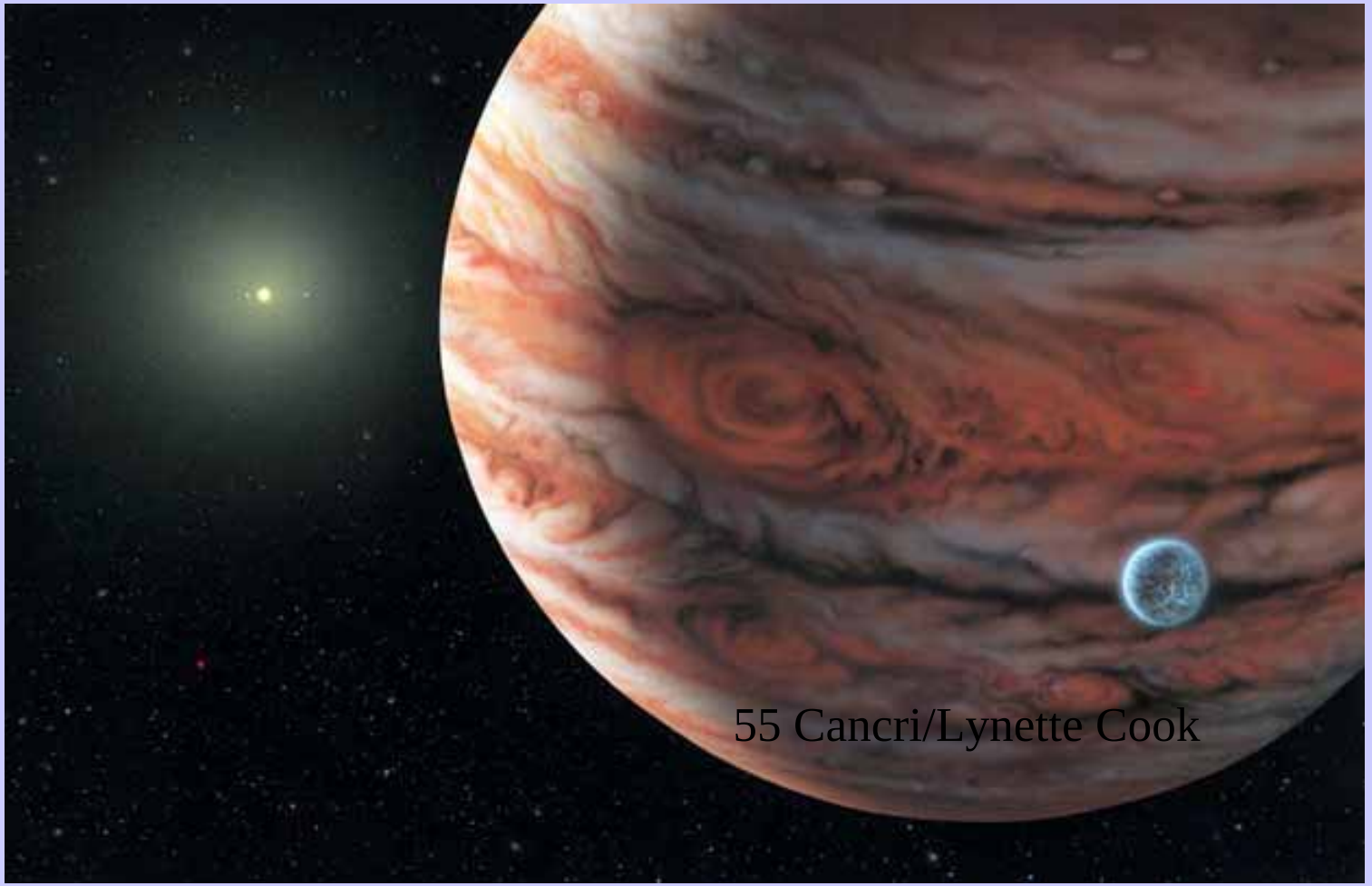


J.-L. Beuzit et al. (Grenoble Obs.), ESO



C. R. O'Dell and S. K. Wong, Rice U., WFPC2, HST, NASA

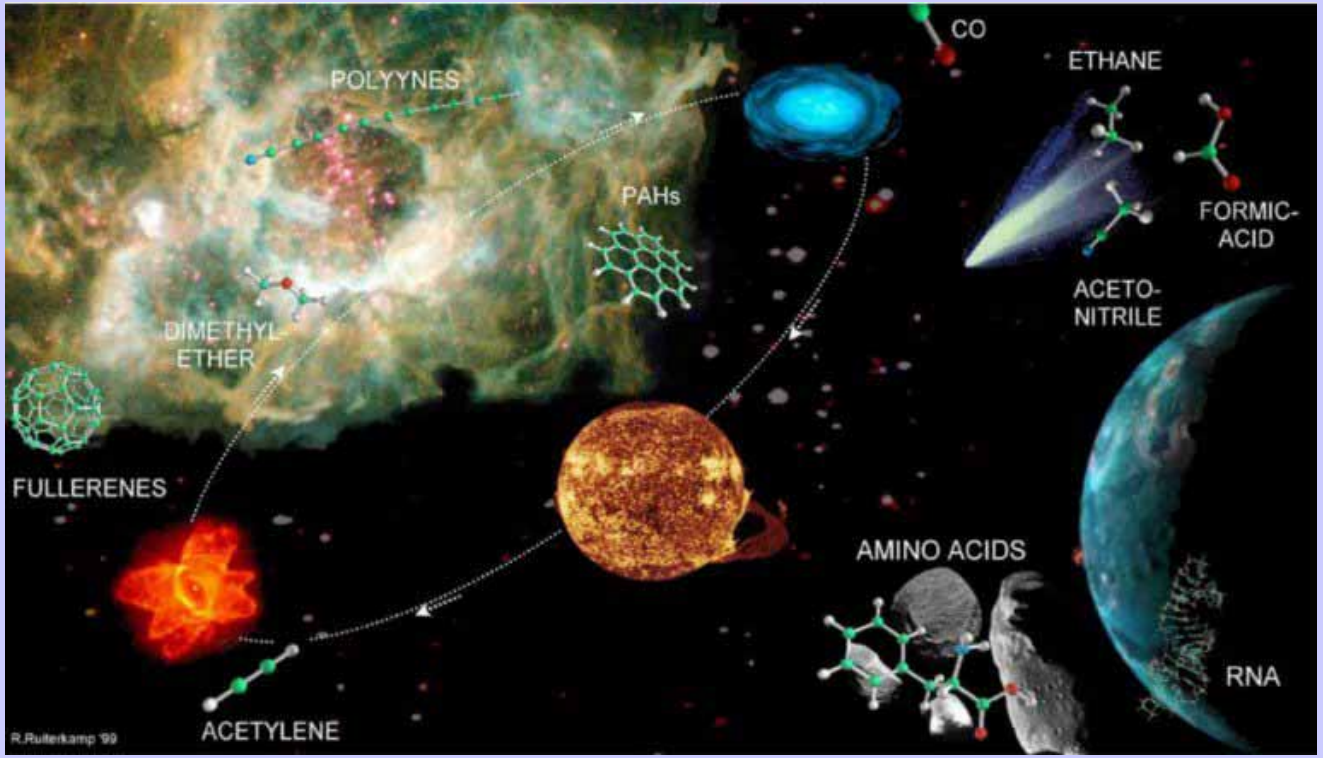
Real Planets!



Origins of Life

Hydrothermal Vent
University of Victoria

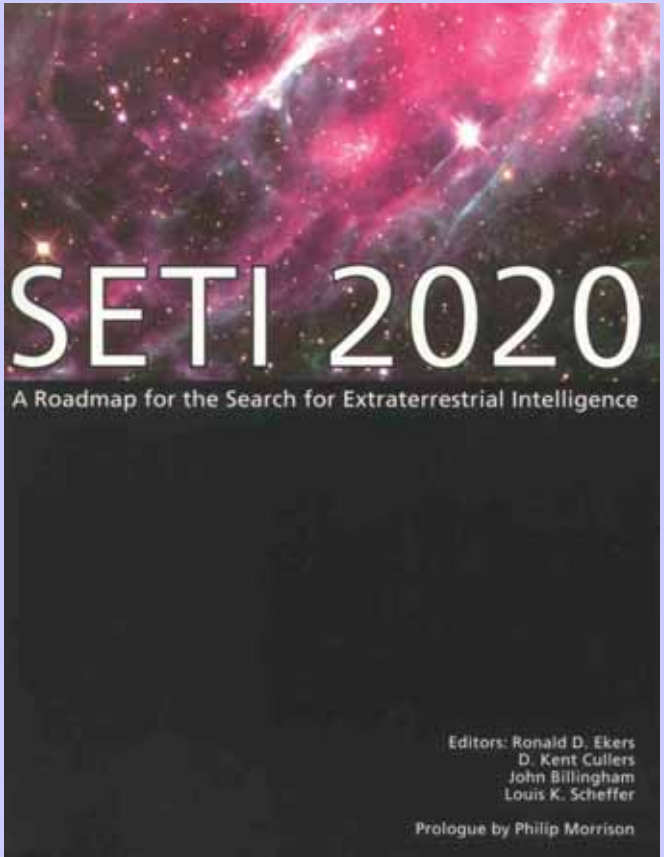
Tube Worms
punaridge.org



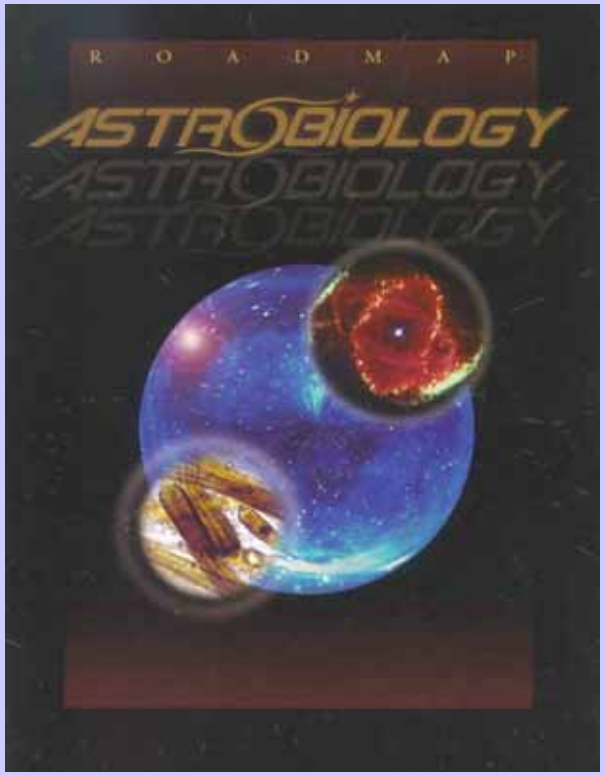
Interstellar Organics

SETI

Allen Array



Astrobiology- Institutional Milestones



- **1995 May. NASA Ames named Astrobiology Lead**
- **1996. NASA Strategic Plan Broaches Astrobiology**
- **1998. Astrobiology Roadmap**
- **1998 May. Eleven Institutions become charter members of Astrobiology Institute**
- **1999 May. Baruch Blumberg Named NAI Director**
- **2001. Four more Institutions join NAI**
- **2002. September. Bruce Runnegar named NAI Director**
  Rosalind Grimes is Acting Director until 2003
- **2003. Twelve NAI Team Leads replace original 11**
- **2003 Revised Astrobiology Roadmap**

The NASA Vision

To improve life here

To extend life to there

To find life beyond

The NASA Mission

To understand and protect our home planet

To explore the universe and search for life

To inspire the next generation of explorers

… as only NASA can

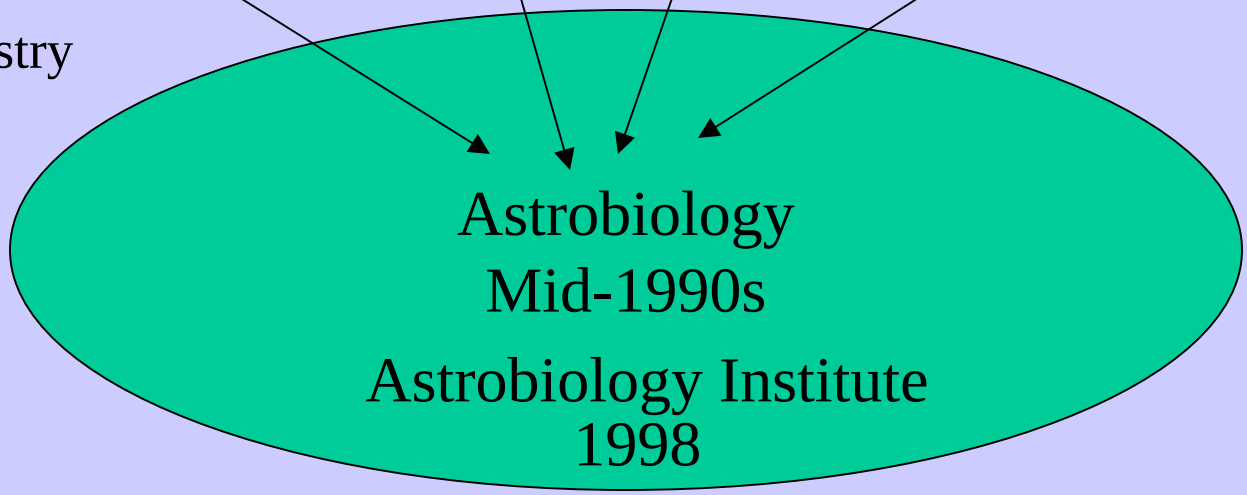
Coalescence of a New Discipline

Planetary Systems
Circumstellar Disks
Extrasolar Planets
Kepler, SIM, TPF
Biosignatures
Theoretical studies

Origins of Life
Genomics/Phylogenetic relationships
Life in Extreme Environments
Complex Organics Simulations and Obsns
Laboratory Prebiotic Experiments

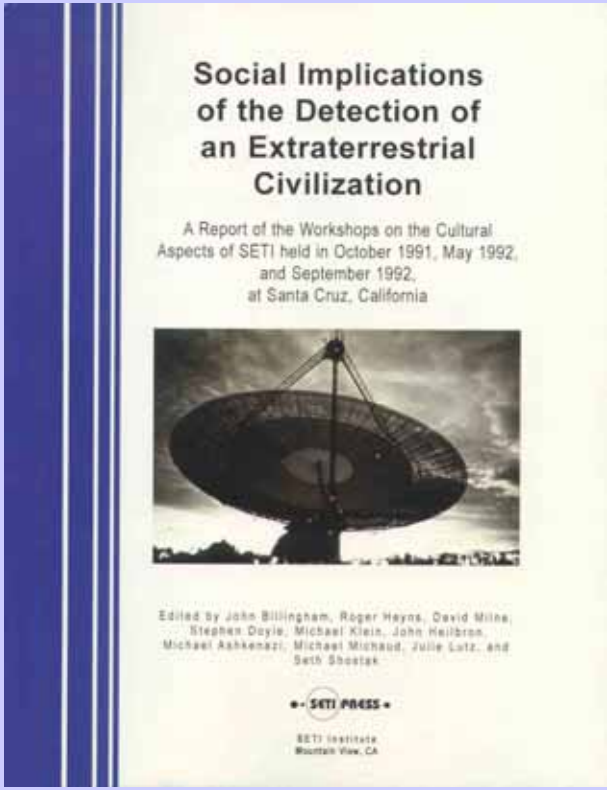
Planetary Science
Mars Rock
Europa
Geochemistry
Biogeochemistry

SETI
Allen Array
SETI at Home
SETI 2020 Roadmap



Implications of Astrobiology

Studies of Implications of Astrobiology



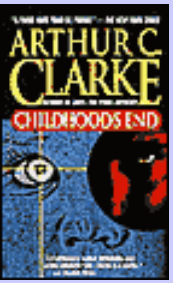
- 1991-1992 NASA CASETI Workshops
- 1999 NASA Workshop on Societal Implications of Astrobiology
- Templeton Foundation Workshops
- Foundation for the Future Studies
- AAAS Program of Dialogue Between Science and Religion

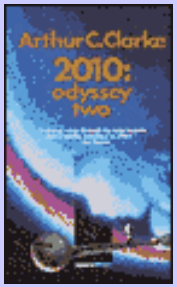
TABLE 1

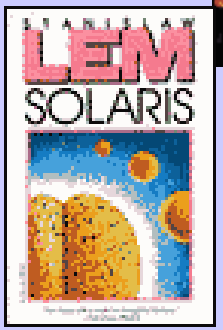
Stages in World View Development

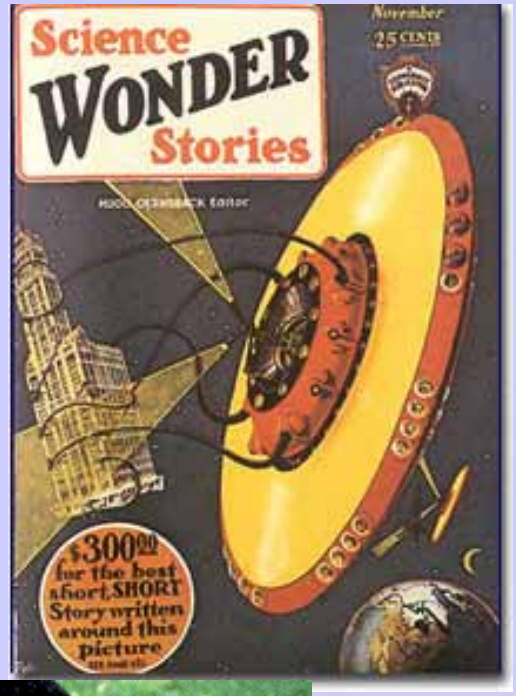
Stage	Geocentric	Heliocentric	Galactocentric	Extraterrestrial/ Biophysical
Motivation	motion of planets anthropocentrism	motion of planets Neoplatonism geocentric problems	globular cluster distribution	Copernican theory cosmic evolution
Presentation Based on Observation	Eudoxus/ Aristotle 4th century BC	Copernicus 1543	Shapley 1917	Kepler (disproven) Lowell (disproven) Viking (unlikely) radio signal? Martian meteorite?
Elaboration	Ptolemy et al.	Galileo, Kepler, Newton, et al.	Trumpler, Oort, et al.	scientists
Opposition	antirationalists	geocentrists religious	Curtis, et al.	religious philosophical scientific
Exploration of Implications Outside Field	anthropocentric religions and philosophies	philosophical literary scientific	further proof of nonanthropo-centrism	all aspects of human knowledge
General Acceptance	4th century BC	1700	1930s	widely accepted 1750
Final Confirmation	disproven	1838 (stellar parallax = Earth motion)	1950s (radio maps of galaxy)	deciphered signal? UFO identified? life on Mars/ Europa, etc.? Martian meteorite?

ETI in Popular Culture









Two Chief World Systems
21st Century
The Physical Universe vs. The Biological Universe

Cosmic Evolution

Big Bang
Galaxies
Stars
Biogenic Elements
Planets
Chemical Evolution
Origin of Life

Precambrian Biology
Complex Life
Intelligent Life
Cultural Evolution
Civilizations
Science and Technology
Study of Life in the Universe

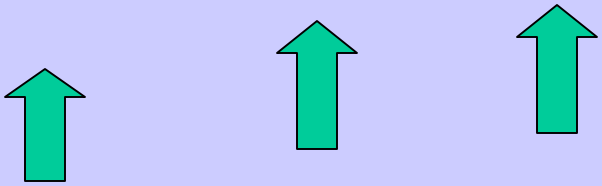
Source: NASA SETI Program, 1979

Cultural Evolution

Cultural Evolution must be seen as an Integral Part of Cosmic Evolution and the Drake Equation

The Drake Equation

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$



Astronomical **Biological** **Cultural**

Stapledon- Think Long-Term!

Long-term "Stapledonian" Thinking may be Necessary To Understand the Nature of Intelligence In the Universe Today, if it is Indeed Widespread

Humans not Accustomed to Thinking on Cosmic Time Scales for Biology and Culture!

A Postbiological Universe?

1) The Maximum Age (A) of ETI is Several Billion Years

2) The Lifetime (L) of a Technological Civilization is > 100 Years and Probably Much Larger

3) In the Long Term Cultural Evolution Supersedes Biological Evolution, and Would Produce Something Far Beyond Biology

Summary

- **The Biological Universe is a World View**
- **We are on the Brink of Deciding Between Two World Views**
- **Astrobiology is the Science that will Provide the Critical Data**
- **Either Way, there will be Long-term /Short-term Societal Impact**

Omega Centauri/Loke Kun Tan